Revolutionary Approaches to Produce Innovative Design Technologies

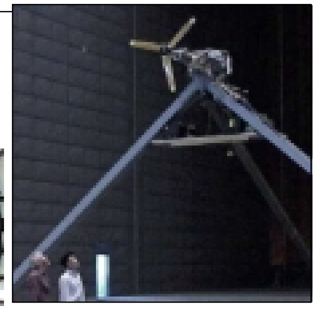
Sept 5, 2001

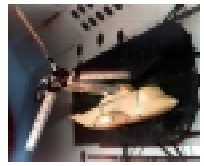
Robert M. Kufeld, Project Mgr.

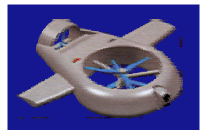
Project Overview

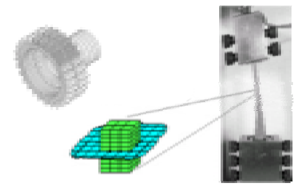
Rotorcraft Program

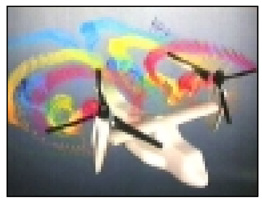
RAPID Revolutionary Approaches to Produce Innovative Design Technologies











Project Goal

Revolutionize vertical flight & design to enable vertical flight as a solution to the Nation's "throughput and mobility" problems.

Objectives

1. Develop validated, fast, accurate, physics-based models design tools for
   1. aeromechanics predictions of revolutionary rotor concepts
   2. composite structures
   3. transmission fatigue life prediction
2. Integrate emerging design tools and processes into industry for the design of revolutionary rotary wing vehicle.

Benefit

Significant reductions in development time, cost of operation and ownership, and cost per passenger mile while increasing passenger acceptance of vertical lift vehicles.

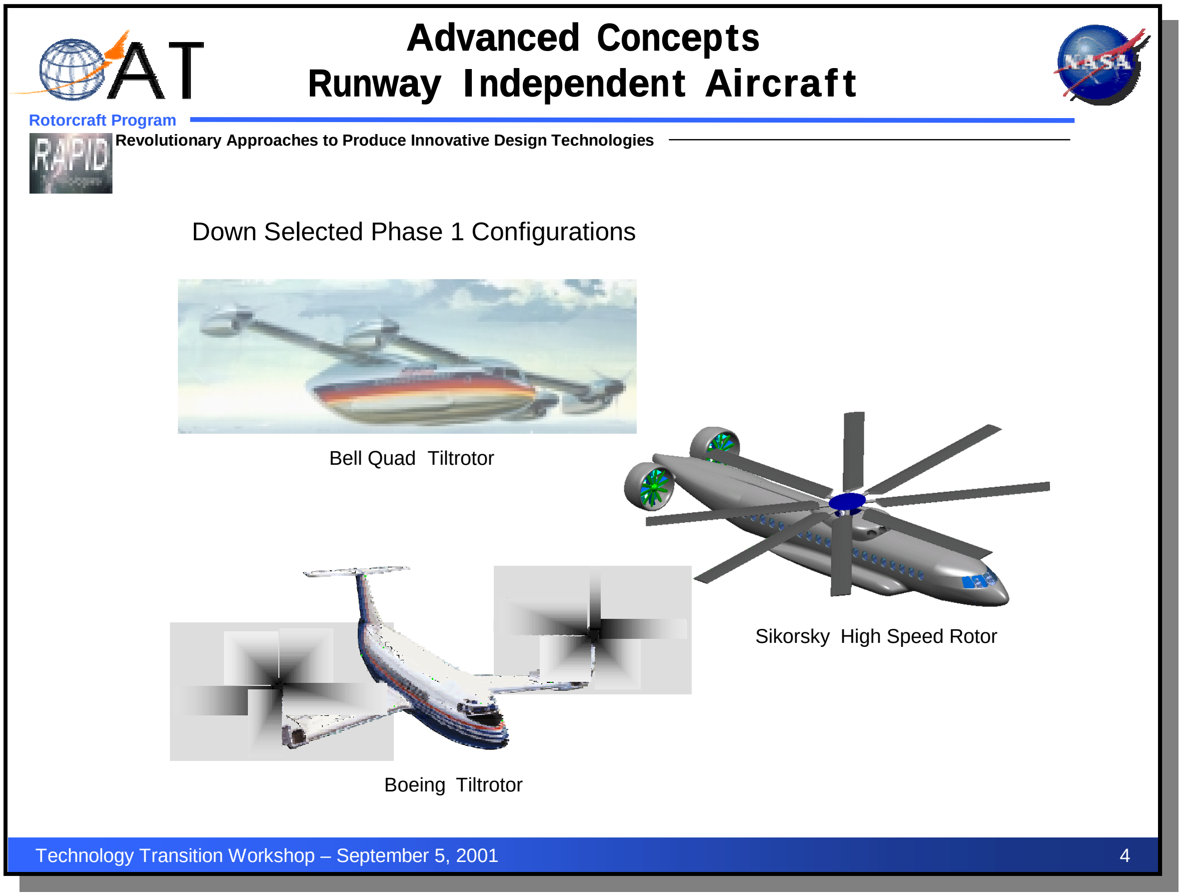
- **Aeromechanics**
- **Composite Structures**
- **Transmissions**
- **Physics-based Design Tools**
- **Revolutionary Concepts**
- **Experimental Validations**

RAPID/SILNT Projects
Ames Research Center

Rotorcraft Program

Revolutionary Approaches to Produce Innovative Design Technologies

- •Advanced Configurations
  - •Runway Independent Aircraft Concepts
  - •Parametric Design/Cost Model
  - •Variable Diameter Tilt Rotor Demonstrator
  - •Swashplateless Flight Demonstrator
  - •Ducted Fan
- •Physics-Based Models Development
  - •Modeling of Rotorcraft Aerodynamics
  - •Modeling and Validation of Hovering Rotor
  - •Real Time Rotorcraft Free Wake Modeling
  - •UH-60 Airloads
  - •Unsteady Aero
  - •Applied Particle Image Velocimetry
- •Tilt Rotor Aerodynamic/Acoustic
  - •Tiltrotor Aeroacoustic Model
  - •Adaptive Flow Control/Download Reduction
  - •Tiltrotor Descent Aerodynamics 80x120
  - •Tiltrotor Descent Aerodynamics 7x10
  - •Tiltrotor Aeromechanics Assessment Committee
- •Noise/Vibration control
  - •Active Noise Controller Development
  - •Individual Blade Control
  - •Smart Rotor
  - •Active Elevon Rotor
  - •Intelligent Noise and Vibration Control



Goal

The goal of these design studies is to developed information that will identify technology barriers, payoffs, and priorities for future rotorcraft research. The study will provide initial information on a range of conceptual designs of advanced vertical lift solutions that could serve as part of the national air transportation system. This information is intended to:

1. Identify candidate solutions that embody advanced vertical flight technology
2. Enable selected solutions to be assessed using the NASA systems analysis models to determine the potential benefits of vertical flight as part of the air transportation system
3. Establish goals for future research in vertical flight technology

These solutions should be capable of providing attractive, reliable, and affordable service from vertiports, general aviation airports, or hub airports in simultaneous non-interfering operations. This supports NASA's goals for Capacity and Mobility.

Accomplishments to Date

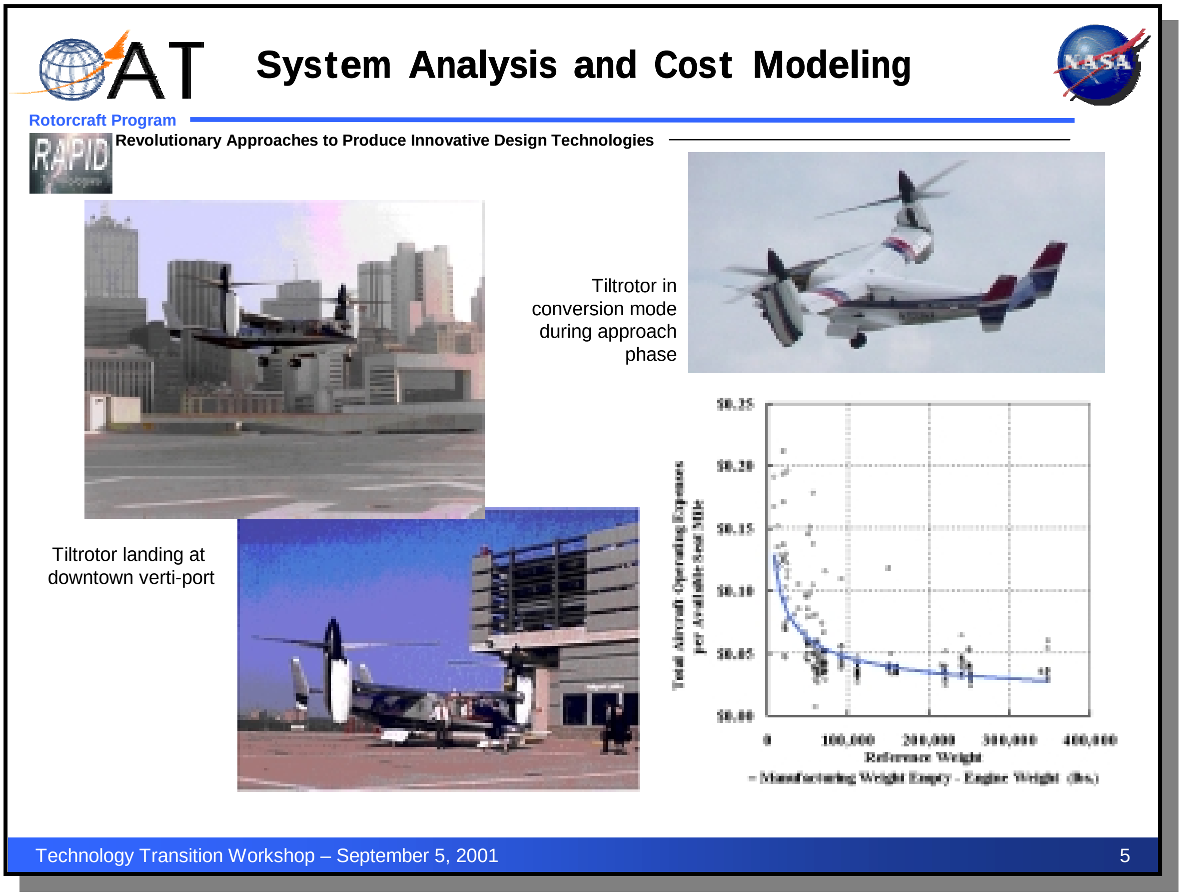
Three contractor completed assessment of a wide verity of concepts for a 200-to 600 mile transport carrying 40 to 120 passengers judging them with Cost per seat mile, noise, speed, and reported results. Currently each contractor doing detail study of the down selected concept.

Future Plans / Opportunities

Complete detail study and report results and incorporate findings into NASA's Air Transportation System Study.

POC

George Price, Ames Research Center (650) 604-4549, gprice@mail.arc.nasa.gov



Goal

Develop an in-house capability to predict the cost and performance of conventional and advance rotorcraft as they operate within the National transportation system This supports NASA's goals for Capacity and Mobility.

Accomplishments to Date

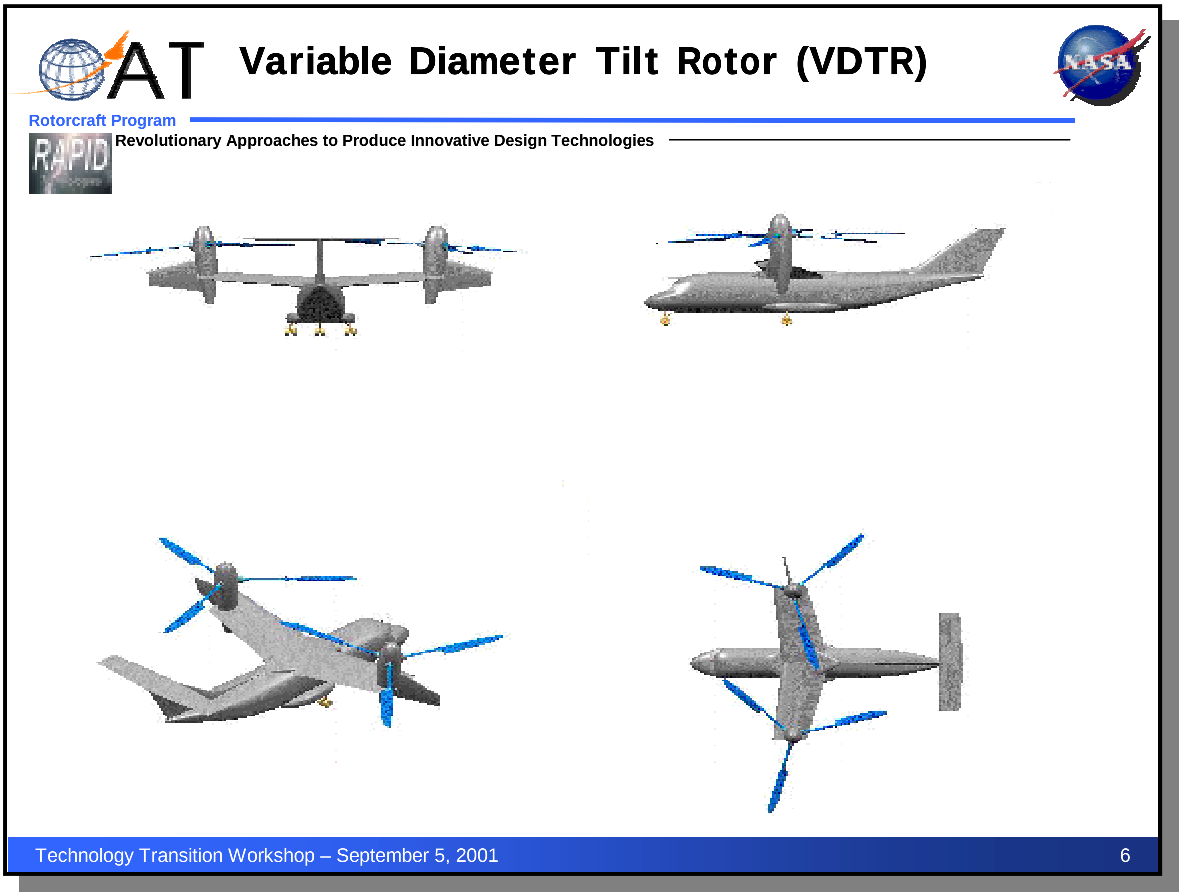
The source code for VASCOMP (1986,1997,2000) and HESCOMP parametric design codes were obtained and studied. Develop and improved the VASCOMP input glossary using Spreadsheet macros to facilitate the generation of input parameters. Updated the 1983 documentation. Exercised HESCOMP and VASCOMP programs for advance rotorcraft to ensure the codes were operational. Studied the commercially available cost data for airliners to validate existing cost models and make improvements to the cost model trend equations.

Future Plans / Opportunities

Improve the cost model for rotorcraft by expansion of the number of cost trend equations as function of design and performance parameters. Complete documentation update. Perform parametric design studies for advanced rotorcraft using the HESCOMP and VASCOMP codes.

POC

Johannes M. van Aken Ames Research Center (650) 604-6668 jvanaken@mail.arc.nasa.gov`



Goal
The goal of this work is to build a small-scale flight demonstrator to assess the feasibility of using VDTR to help solve national air transportation system problem. The VTDR will provide better hover and forward flight performance that regular tilt rotors thus providing better operating cost. This supports NASA's goals for Capacity, Mobility and Technology Innovation

Accomplishments to Date
Completed conceptual design layout of the proposed demonstrator and submitted report on performance for inclusion in the national air transportation system study.

Future Plans / Opportunities
Plans include building a flight demonstrator, testing in wind tunnel, and flight testing and reporting results if Phase II REVCON funding is approved.

Partners
NASA REVCON, Sikorsky

POC
John Madden, Ames Research Center, (650) 604-4590, jmadden@mail.arc.nasa.gov

Goal

The goal of this work is to build a small-scale flight demonstrator to assess the feasibility of using Swashplateless control to help solve national air transportation system problem. The swashplateless rotor will provide individual blade control and reduce maintenance, improving performance, and reducing operating cost. This supports NASA's goals for Capacity, Mobility and Technology Innovation

Accomplishments to Date

Completed conceptual design layout of the proposed demonstrator, complete construction of fuselage, and submitted report on performance for inclusion in the national air transportation system study.

Future Plans / Opportunities

Plans include completing a flight/wind tunnel test vehicle, testing in wind tunnel, flight testing computational modeling and reporting results if phase II REVCON is approved.

Partners

NASA REVCON

POC

Khanh Nguyen, Ames Research Center, (650) 604-5043, knguyen@mail.arc.nasa.gov

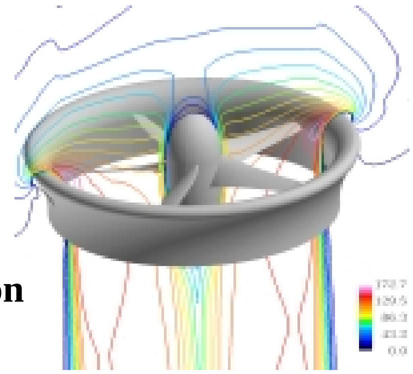
RAPID

Rotorcraft Program

Revolutionary Approaches to Produce Innovative Design Technologies

Ducted Fan Investigation

7- by 10- ft Wind Tunnel Installation



Velocity Contours

Technology Transition Workshop – September 5, 2001 8

Goal

The goal of the work is to evaluate performance of an alternative lift system for a microvehicle lift platform. This supports NASA's goals for Mobility and Technology Innovation.

Accomplishments to Date

A wind tunnel test was used to study the effects of ducted fan geometry and a CFD analysis was used to provide a baseline for correlation with experimental measurements.

Future Plans / Opportunities

Document results of test. A paper will be given this January at AHS Aeromechanics Conference in San Francisco. Assess the adequacy of design for microvehicle.

Partners

Millennium Jet, DARPA

POC

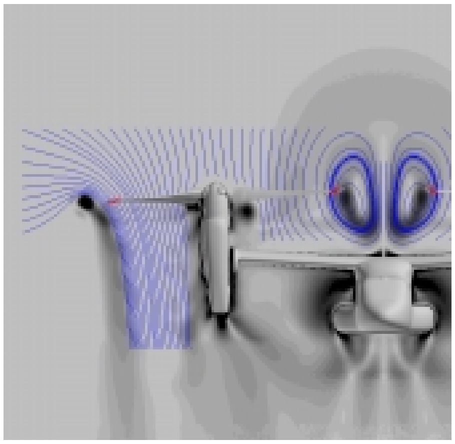
Anita Abrego, Ames Research Center, (650) 604-2565, aabrego@mail.arc.nasa.gov

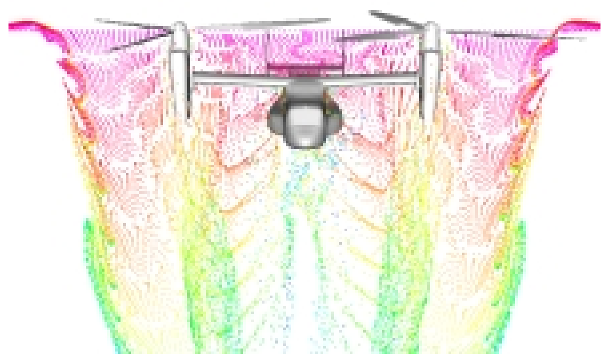
Rotorcraft Program

Revolutionary Approaches to Produce Innovative Design Technologies

Computational Modeling Rotorcraft Aerodynamics

CFD Calculated Hover Flowfields





V-22
Vorticity contours (B/W) and confined streamlines (blue)

VDTR
Time dependent particle traces

Goal

The goal of the work is to develop advance Computational Fluid Dynamics tools and applied them to complex configuration. This work supports NASA's goal for Technology Innovation.

Accomplishments to Date

Completed comparison of baseline V-22 and Variable Diameter Tilt Rotor (VDTR) hover flowfields and performance using large-scale, high fidelity, turbulent flow, moving body simulation. The CFD tool development resulted in an average reduction in computational cost on parallel processors of 50%.

Future Plans / Opportunities

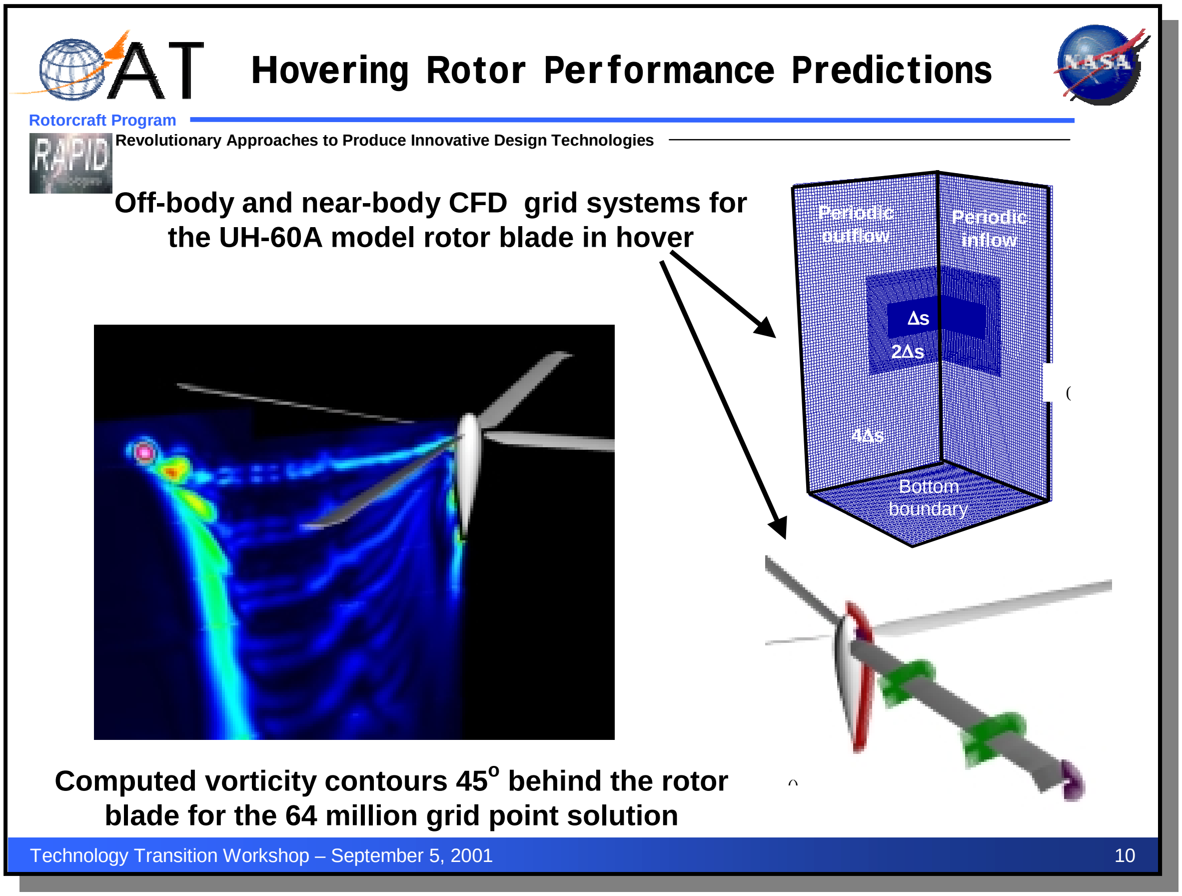
Improve dynamic CFD simulation with efficiency and ease of use enhancements and demonstrate CFD tool on NASA information Power Grid

Partners

Army, DARPA

POC

Mark Potsdam, Ames Research Center, (650) 604-4455, mpatsdam@mail.arc.nasa.gov



Goal

Validations of large-scale computation tool to predict the performance of an UH-60 rotor in hover with high numerical resolution to carefully control numerical effects and accuracy. This work supports NASA's goal for Technology Innovation.

Accomplishments to Date

Large-scale computations have been conducted. Baseline computation used 10.6 million grid points and one high-resolution simulation used 64 million points. The 64 million grid points pushes the limit of current high performance computer capacity. All solutions show very good agreement with experimentally measured rotor performance. The computations show the high-resolution grid can produce high-accuracy performance results and a wealth of detailed flowfield information.

Future Plans / Opportunities

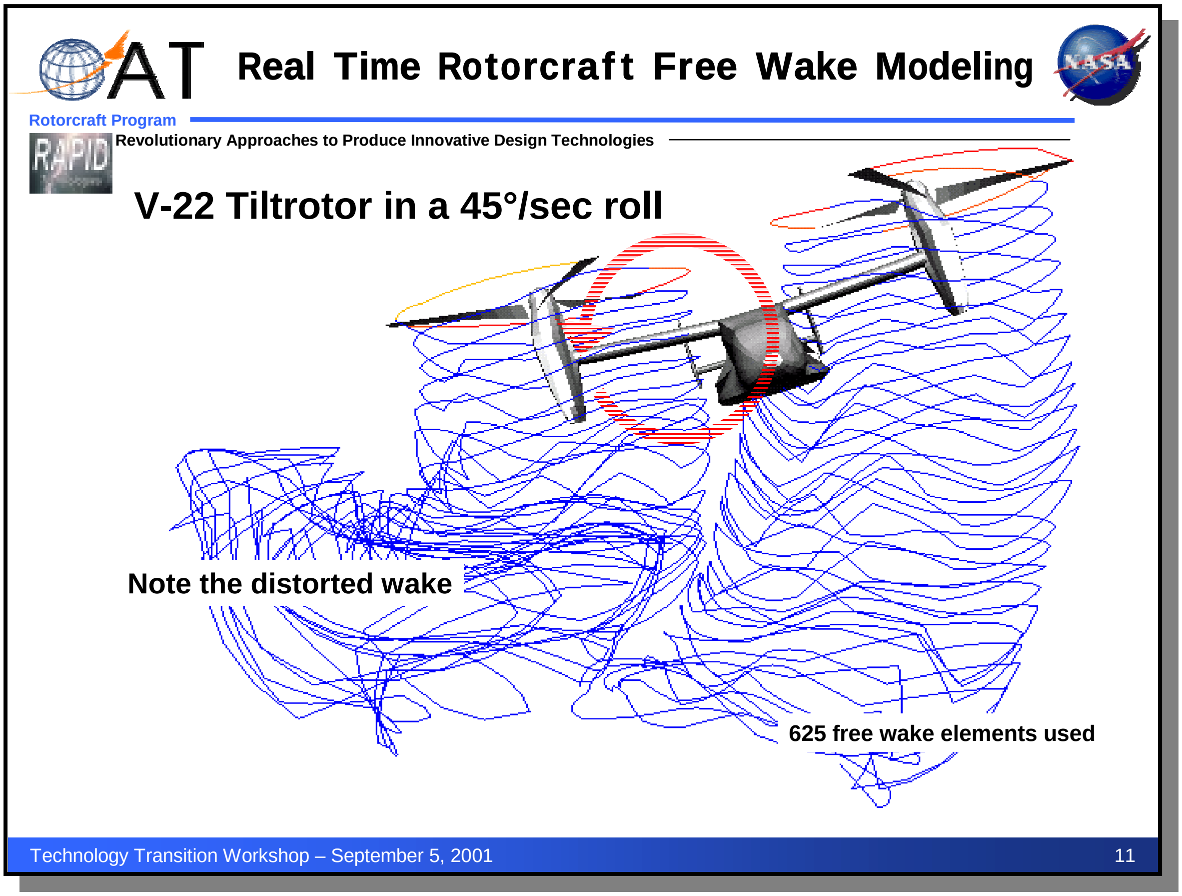
Develop code for computation on massively parallel computer to prepare for validation efforts on more complicated unsteady rotor simulations in forward-flight.

Partners

Army

POC

Dr. Roger Strawn, Ames Research Center, (650) 604-4510, rstrawn@mail.arc.nasa.gov



Goal
Develop complex, realistic rotor wake algorithms with fast CPU cycles time to enhance real time rotorcraft simulation used to support control system design and crew training. This work supports NASA's goal for Technology Innovation.

Accomplishments to Date
The aerodynamic wake models have been completed and can now support high fidelity, real time simulation of free wakes from rotorcraft. This capability has been demonstrated on both a conventional stand-alone serial processing workstation as well as in a code "module" to Sikorsky's GenHel full rotorcraft simulation.

Future Plans / Opportunities
Validation for the real time free wake module will be carried out by CDI and Sikorsky, simulating steady and maneuvering flight in GenHel. Project reporting, model documentation and training of NASA personnel will be completed soon.

Partners
CDI (NASA SBIR Program)

POC
Tom Norman, Ames Research Center, (650) 604-6653 tnorman@mail.arc.nasa.gov

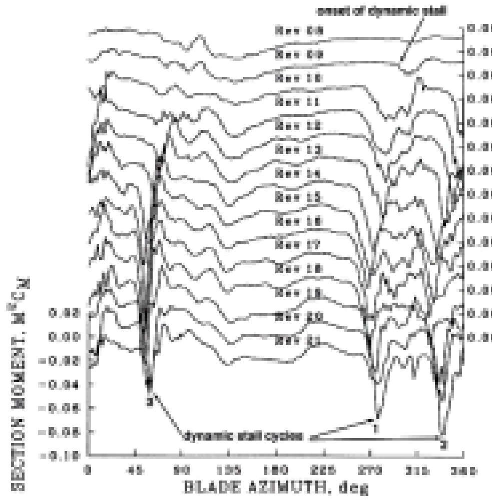
UH-60 Airloads Project

Rotorcraft Program

Revolutionary Approaches to Produce Innovative Design Technologies

UH-60 UTTAS Maneuver

Section moment at r/R = 0.865



Technology Transition Workshop – September 5, 2001 12

Goal

The goal is to obtain comprehensive, accurate, documented airloads over the complete operating limits of the UH—60 rotor system that will have long-term value and widespread accessibility so that the rotorcraft community can increase their understanding of rotor behavior, refine and validate their analysis tools, and design improve rotorcraft. This supports NASA's goals for Capacity, Mobility and Technology Innovation

Accomplishments to Date

Completed a small-scale wind tunnel test in DNW and a full-scale flight test including maneuvers and acoustic. A large easy accessible database is maintained by NASA for use by industry and DOD. Several papers published and validation of prediction tools have been preformed. NRTC has used data to help improve prediction tools.

Future Plans / Opportunities

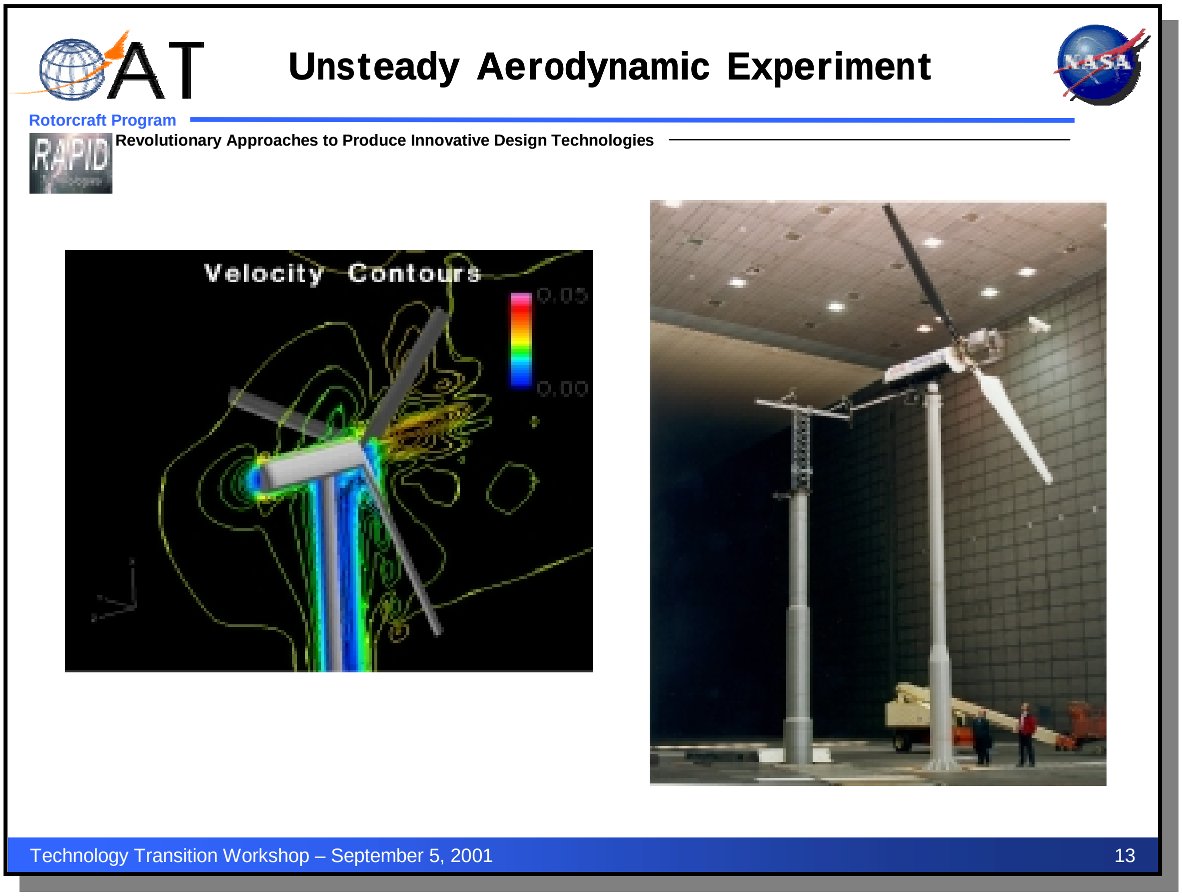
Maintain database and continue uses of data for validations. NRTC has initiated a new effort to improve the industry prediction codes using airload data for validation. Publish addition documentation. Collect wind tunnel measurements of the rotor airloads.

Partners

Army

POC

William Bousman, Ames Research Center (650) 604-3748, wbousman@mail.arc.nasa.gov



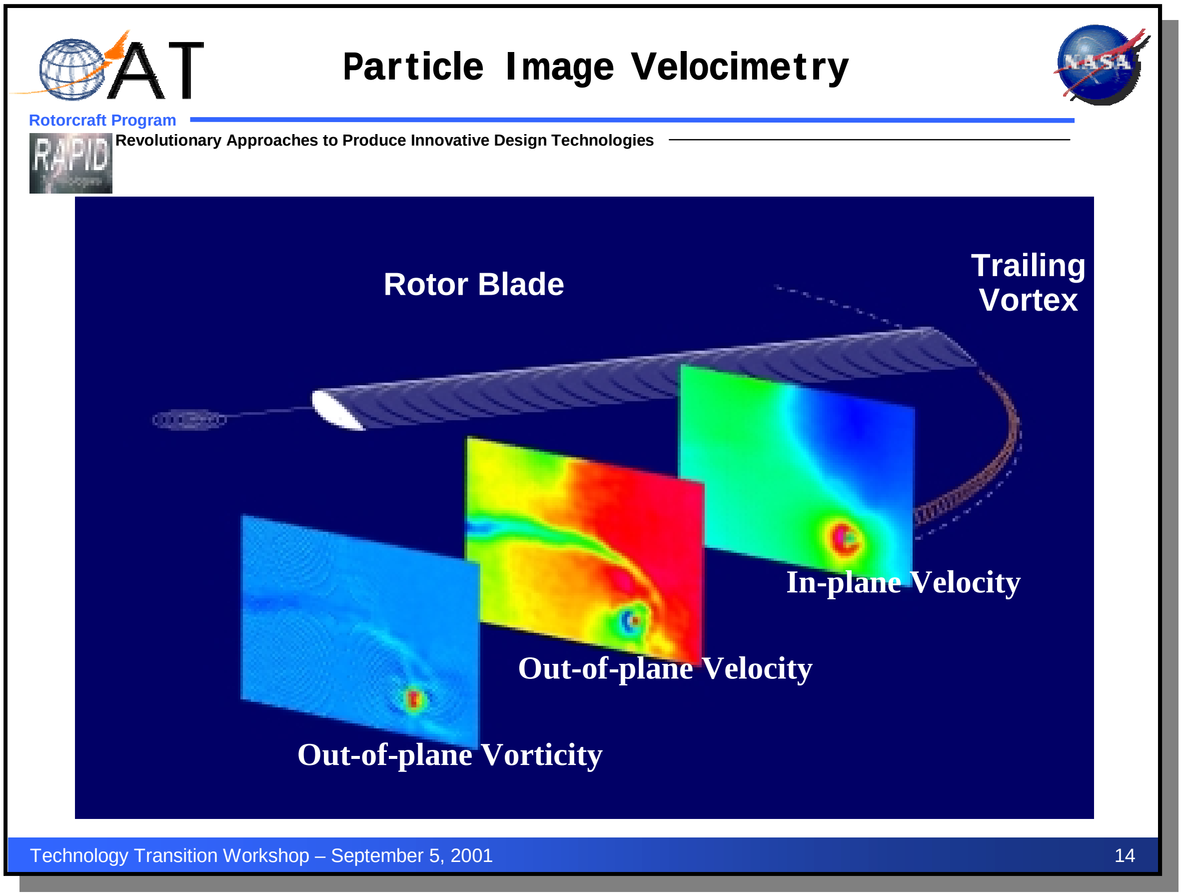
Goal
The goal of this project was to collect a complete set of aerodynamic loading information for a horizontal axis wind turbine over its full operating envelope using NASA Ames 80- x120-ft wind tunnel and a highly instrumented pressure blade. The wind turbine was also model using unsteady Reynolds averaged Navier-Stokes simulation (CFD calculation). The data will be used to validate current performance and loads predictions codes and the CFD models give insight to help develop aerodynamics models for rotor design codes). This work supports NASA's goal for Technology Innovation.

Accomplishments to Date
The test was completed in June 2000. CFD as well as comprehensive models were developed and exercised. Comparison to experimental results was made. A blind comparison with over ten different analyses was completed in November. Detail study of the stall delay is currently underway.

Future Plans / Opportunities
Continue stall delay study work with DOE and work with DOE to develop Aeroacoustic codes.

Partners
DOE

POC
Robert Kufeld, Ames Research Center, (650) 604-5664, rkufeld@mail.arc.nasa.gov



Goal

Develop a visualization tool to allow a rapid means for discovering the detailed structure of a vortex that trails from the tip of a hovering rotor. This tool will be used to validate complex rotorcraft wake theory, increase the understanding of vortex dynamic and allow a quantitative evaluation of various wake altering devices. This work supports NASA's goal for Technology Innovation.

Accomplishments to Date

Velocimetry measurements of tip vortex strength with various wake altering devices were made.

Future Plans / Opportunities

High resolution measurements in the near wake of main rotor blade will be used to develop and validate a theory designed to separately determine rotor thrust, profile drag and induce drag and define the aging and blade interaction on the structure of the vortex

Partners

Army

POC

Dr. Kenneth McAlister, Ames Research Center (650) 604-5892, kmcalister@mail.arc.nasa.gov

AT

TRAM in 40- by 80-Foot Wind Tunnel

Rotorcraft Program

RAPID Revolutionary Approaches to Produce Innovative Design Technologies

Technology Transition Workshop – September 5, 2001 15

Goal

Develop and demonstrate a state-of-the-art tiltrotor test-bed. Acquire aeroacoustic database for validation of design tools required for tiltrotor noise reduction. This work supports NASA's goal for Noise reduction, Capacity, and Mobility.

Accomplishments to Date

Hover and forward flight wind tunnel testing was performed acquiring rotor blade structural loads, rotor and fuselage balance loads, and wing pressures, acoustics and flow visualization.

Future Plans / Opportunities

Continued development of model is planned and further testing will be performed in the 80-by 120-foot wind tunnel in late 2001. Advanced tiltrotor technologies and vehicle configurations will be validated/ demonstrated in the future using TRAM.

Partners

NASA SHCT Project

POC

Megan McCluer. Ames Research Center (650) 604-0010, mmccluer@mail.arc.nasa.gov

Rotorcraft Program

RAPID Revolutionary Approaches to Produce Innovative Design Technologies

Full-Span TRAM
Adaptive Flow Control/Download Reduction

- 0.25 Scale V-22
- R = 4.75 ft (1.48 m)
- 3 Six-component balances
- 2 Electric drive motors, 300 HP each
- Bayonet mount, -9 to +18 degrees AOA
- Aeroelastically scaled rotors
- 150 Dynamic transducers in right-hand rotor
- 80-by 120-ft wind tunnel entry in FY 02

Technology Transition Workshop – September 5, 2001 16

Goal

Use the TRAM with its advance instrumentation and modified with advance controls and flow actuators to reduce the down load during hover and low speed flight. The results should quantify power and flow requirements and help predict load reductions. This supports NASA’s goals for Capacity, Mobility and Technology Innovation

Accomplishments to Date

After successful completion of the first Full-Span TRAM test the model is under-going modifications to prepare for the wind tunnel entry in FY 2002

Future Plans / Opportunities

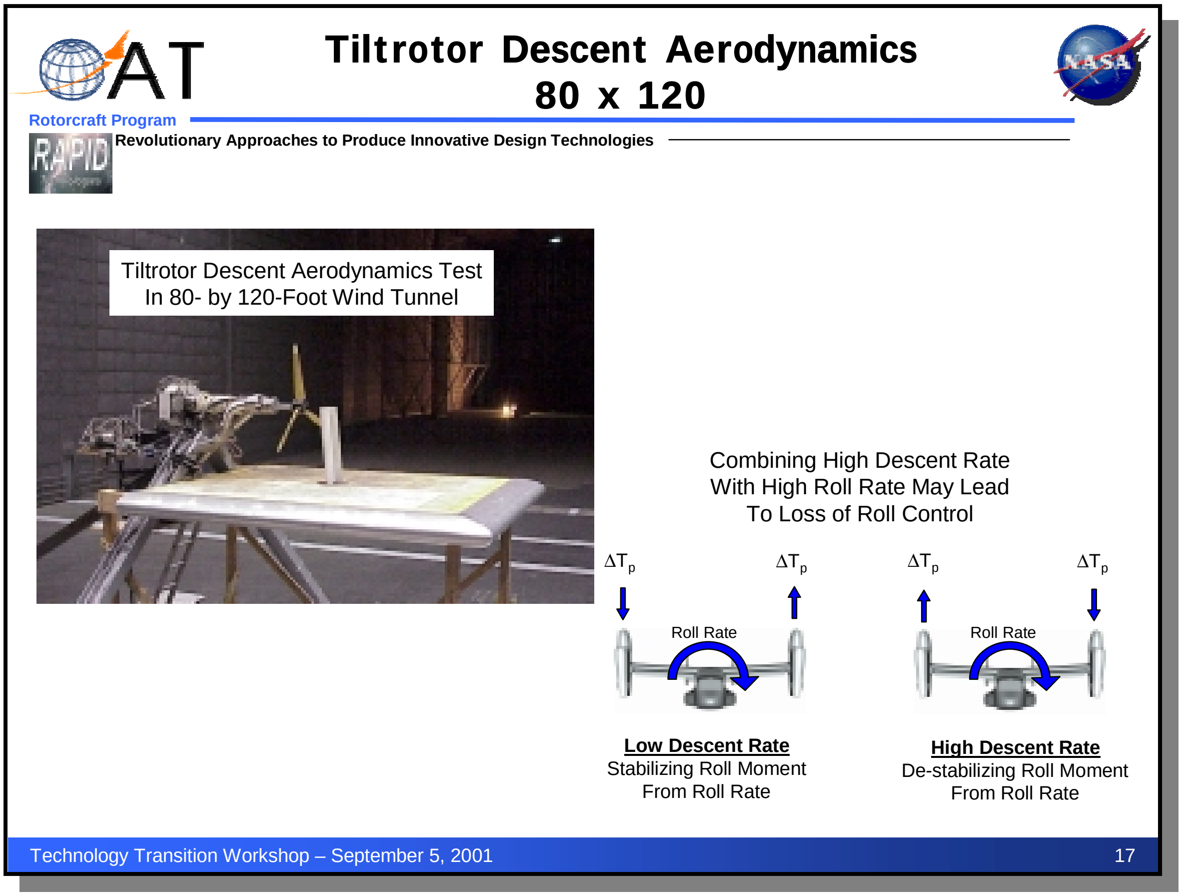
Results from this effort could be used to improve performance of the V-22. TRAM will continue to be a testbed for tilt rotor research.

Partners

DARPA, Boeing

POC

Jeff Johnson, Ames Research Center, (650) 604-6976, jljohnson@mail.arc.nasa.gov



Goal

The goal was to develop accurate model to predict blade loading, including rotor interaction for tilt rotor at high descent rates. This work supports NASA's goal for Capacity and Mobility.

Accomplishments to Date

Completed a low-cost wind tunnel test of tiltrotor at high descent rates and documented flight conditions that put the rotor in a "vortex-ring-state". This is characterized by an unsteady rotor wake and oscillatory rotor thrust. Discovered that when high descent rate is combined with roll rate on a tiltrotor aircraft in helicopter mode, roll moment in the roll direction increases with roll rate, which could lead to loss of roll control

Future Plans / Opportunities

Communicate results to V-22 Integrated Test Team. Use acquired data to validate and improve analytical models. Conduct more wind tunnel experiments to better understand the implications of vortex-ring-state for tiltrotor aircraft.

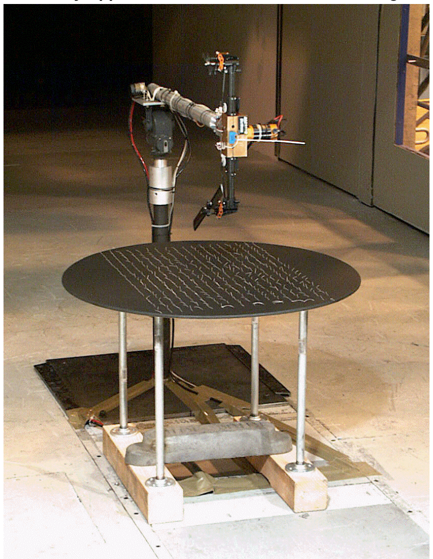
POC

Mark Betzina, Ames Research Center, (650) 604-5106, mbetzina@mail.arc.nasa.gov

Rotorcraft Program

Revolutionary Approaches to Produce Innovative Design Technologies

Tiltrotor Descent Aerodynamics 7x10



Isolated rotor with image plane

Tiltrotor model

Technology Transition Workshop – September 5, 2001 18

Goal

The goal was to develop accurate model to predict blade loading, including rotor interaction for tilt rotor at high descent rates. The use of small-scale models is investigated for the study of descent aerodynamics. If trends match previous testing of larger scale a more productive testing environment could be used. This work supports NASA's goal for Capacity and Mobility.

Accomplishments to Date

An experimental investigation was completed in the 7- by 10-Foot wind tunnel investigating a tiltrotor operating in descent and sideslip conditions. Results show that this small scale model capture the necessary physics to investigate the aerodynamics of interest.

Future Plans / Opportunities

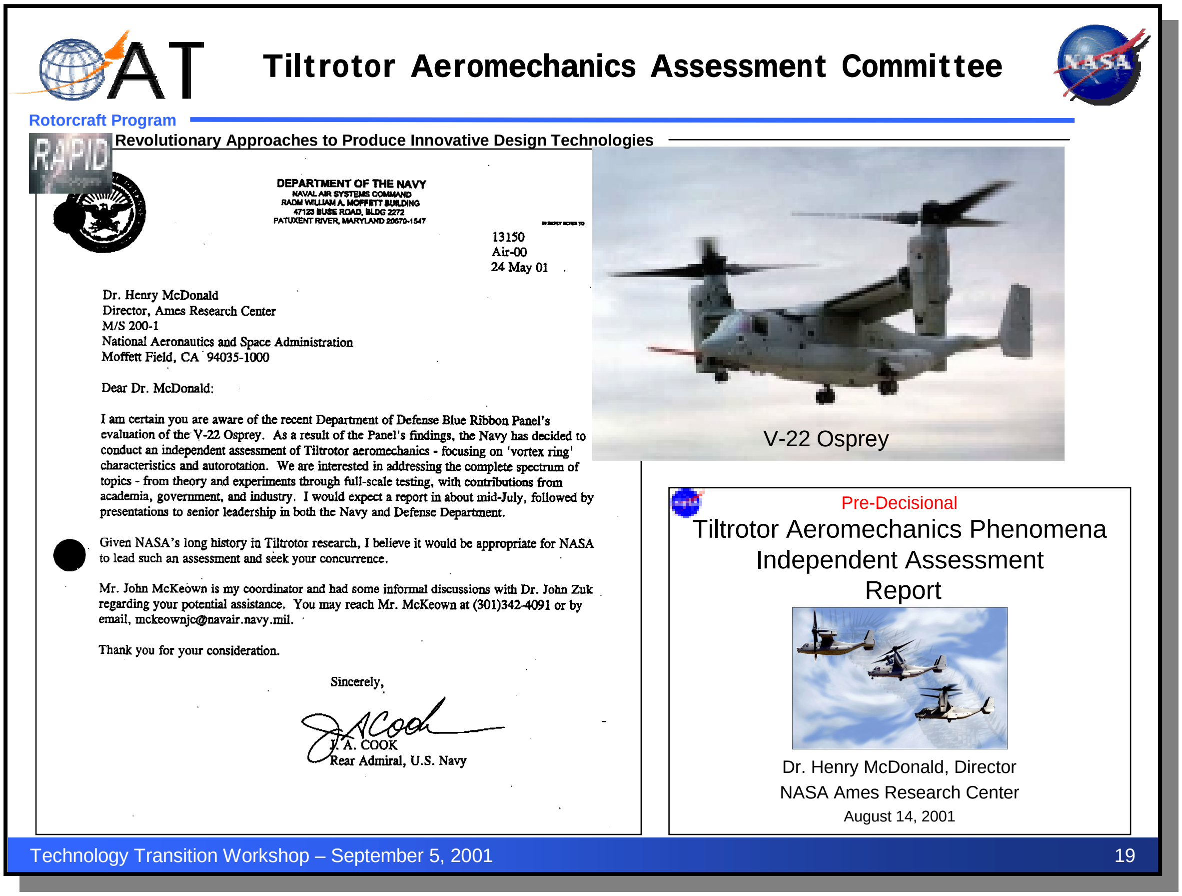
Document results of wind tunnel investigation. Conduct a follow-on test program that will provide higher fidelity information on the ability to model full-span behavior with a single rotor operating in the presence of an image plane. Provide results to U.S. Navy V-22 program to understand fundamental behavior of tiltrotor aircraft in high-speed descent

Partners

Navy

POC

Anita Abrego, Ames Research Center, (650) 604-2565, aabrego@mail.arc.nasa.gov



Goal

To develop a comprehensive assessment and summary of Tiltrotor Aeromechanics Phenomena (vortex ring state, autorotation, low speed maneuvering, etc.) that could be encountered by tiltrotor aircraft. This activity supports NASA's goal for Capacity and Mobility.

Accomplishments to Date

The Naval Air Systems Command requested that NASA lead an "independent assessment of Tiltrotor aeromechanics - focusing on 'vortex ring' characteristics and autorotation." In response to the Navy's request, a committee was established, including both a Technical Team and a Panel to assess the present understanding of tiltrotor aeromechanical phenomena. The Technical Team was led by Ames personnel and included representatives from government, academia, industry and the military. The Panel was chaired by Dr. McDonald and consisted of non-affiliated senior rotorcraft aeromechanics experts. Meeting were held during the summer and the Panel developed finding and recommendation for their final report. Dr. McDonald gave a pre-decisional briefing to Under Secretary of Navy's Office, the Secretary of the Air Force, and the Under Secretary of Defense for Technology and Acquisition in August.

Future Plans / Opportunities

The final written report is due mid-September with a full briefing to the V-22 Program Executive Committee.

Partners

Army, Navy, Air Force, Bell, Boeing

POC

Mark Betzina, Ames Research Center, (650) 604-5106, mbetzina@mail.arc.nasa.gov

Rotorcraft Program

SILNT- Select Integrated Low Noise Technologies

Active Noise Controller Development

XV-15 Rotor in 80- by 120-Foot Wind Tunnel

Technology Transition Workshop – September 5, 2001 20

Goal

Develop and test a controller to reduce rotorcraft blade-vortex interaction (BVI) noise. This work supports NASA’s goal for Noise reduction.

Accomplishments to Date

Demonstrated successful BVI noise reduction using microphone and blade-mounted pressure feedback along with a dedicated signal processing technique for noise detection using higher harmonic control on an XV-15 rotor in the 80x120 wind tunnel.

Future Plans / Opportunities

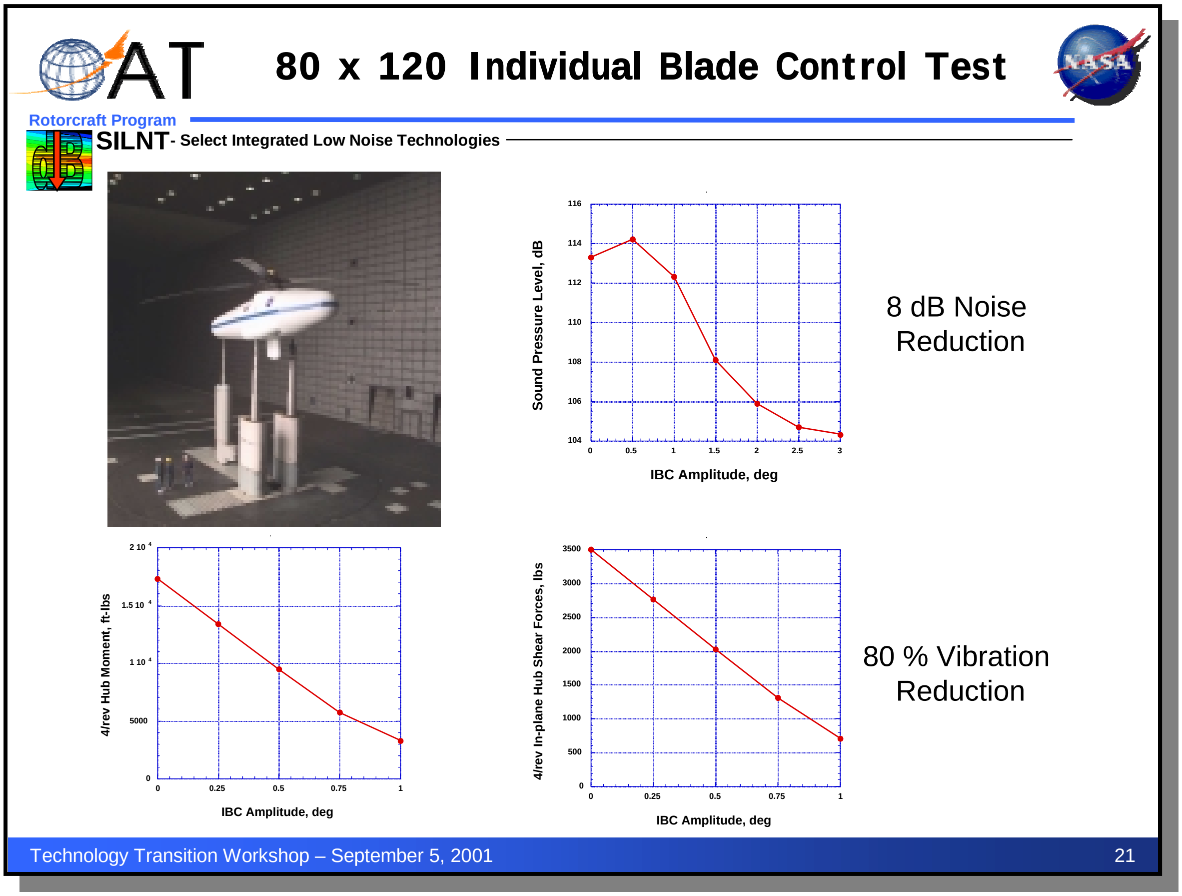
Refine and test controller algorithms for the upcoming individual-blade-control test of the full-scale UH-60 Rotor in the 40- by 80-Foot Wind Tunnel.

Partners

NASA SHCT Project

POC

Khanh Nguyen, Ames Research Center, (650) 604-5043, knguyen@mail.arc.nasa.gov



Goal

The goal of the individual blade control (IBC) system research is to develop the IBC technologies to the point where their effectiveness can be successfully demonstrated in-flight on a production military or civilian helicopter. It is anticipated that IBC will provide very effective rotor system noise suppression, together with substantial reductions in helicopter vibration and increases in rotor performance. This supports NASA's goals for Noise, and Technology Innovation

Accomplishments to Date

The IBC system has been installed, checked out and operated on the LRTA within NASA Ames Research Center's 80x120-ft wind tunnel. Data has been collected for hover and forward flight. The data collected so far have shown 80% reduction in vibration and 8db reduction in noise.

Future Plans / Opportunities

Plan include the completion of current 80x120 test with a follow-on high speed test in 40x80 using current test rig and a set of wide chord UH-60 blades. It is believed vibration reduction of 90% and 12db reduction of BVI noise will be seen. Advance control laws will be investigated. Operation specification such as input amplitude, hydraulic flow rates and power requirements will be determined for moving the IBC system to flight.

Partners

Army, Sikorsky, ZFL

POC

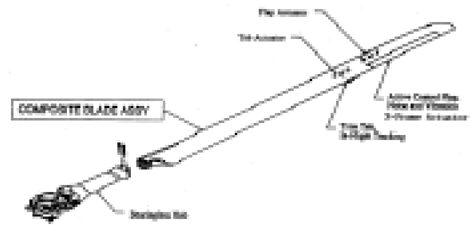
Steve Jacklin, Ames Research Center, (650) 604-4567, sjacklin@mail.arc.nasa.gov

SMART Rotor Development

Rotorcraft Program

SILNT- Select Integrated Low Noise Technologies

Wind Tunnel Test of Full-Scale Smart MD-900 Rotor



Key Components of Smart MD-900 blade

Technology Transition Workshop – September 5, 2001 22

Goal

Demonstrate application of smart materials to rotorcraft through full-scale wind tunnel and flight tests of MD-900 rotor system This supports NASA's goals for Noise, Technology Innovation, and Capacity.

Accomplishments to Date

Demonstrated in a model flap authority sufficient to achieve major aeroelastic benefits. Built and bench tested a full-scale MD-900 smart blade equipped with piezoelectric actuated trailing edge flap. Flight hardware development is 50% complete.

Future Plans / Opportunities

Test the MD-900 Smart rotor in whirl tower Nov. 01,flight test 2nd quarter 02 and in the 40- x 80-Foot Wind Tunnel by the end of FY 02.

Partners

DARPA, Boeing

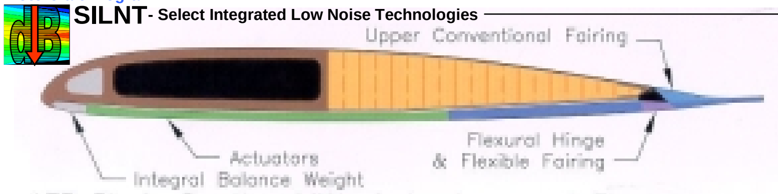
POC

Khanh Nguyen, Ames Research Center, (650) 604-5043, knguyen@mail.arc.nasa.gov

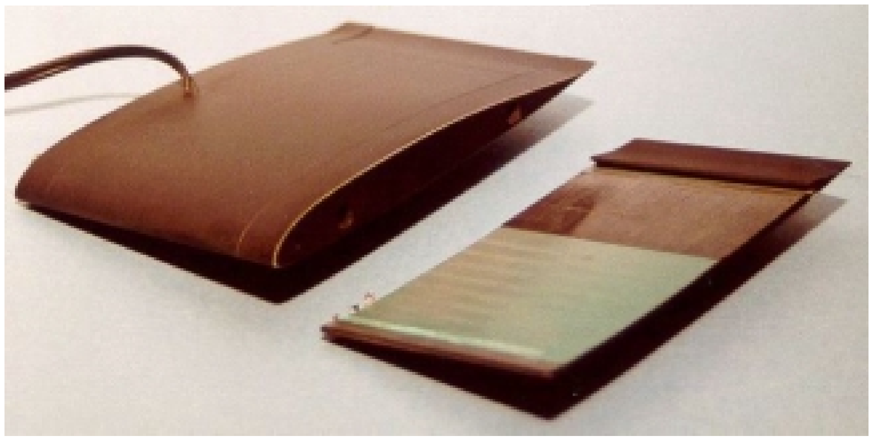
Active Elevon Rotor (AER) Technology for Low Vibration

Rotorcraft Program

SILNT - Select Integrated Low Noise Technologies



AER Blade Section With Actuators and Elevon



Developed by Domzalski Machine under SBIR DAAH10-99-C-0022.

Technology Transition Workshop – September 5, 2001 23

Goal

The goal of the Active Elevon research is to develop the technologies and evaluate their performance within an operational environment. It is anticipated that the active elevon will provide very effective rotor system noise suppression, together with substantial reductions in helicopter vibration and increases in rotor performance. This supports NASA's goals for Noise, Technology Innovation and Capacity.

Accomplishments to Date

Blade preliminary design 25% complete. Rotor diameter is 13 ft., chord 5.67 in., with 15% elevon chord and 0.60 tip Mach No. The elevon will use the Conformal Actuator Technology, developed by Domzalski Machine. Two-dimension Computational Fluid Dynamics calculation have been performed by UC Davis.

Future Plans / Opportunities

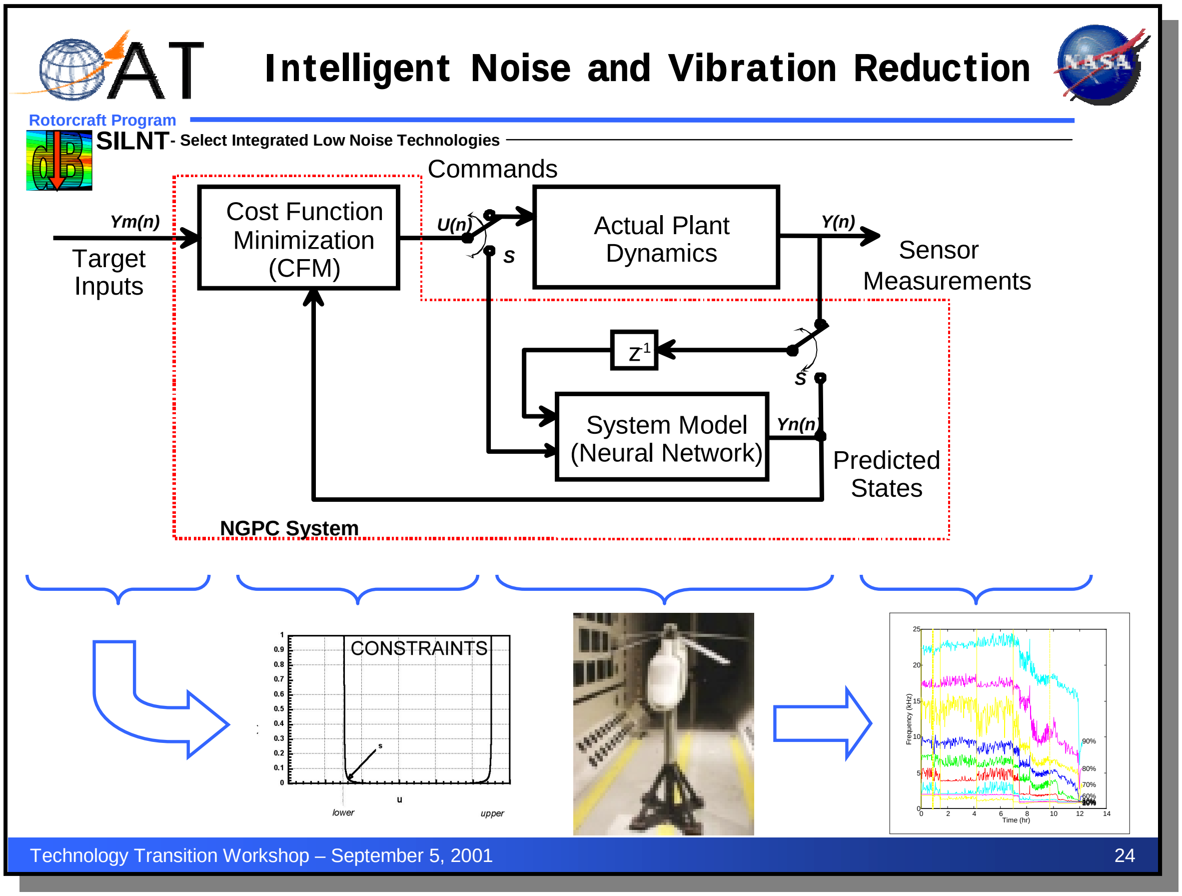
Complete blade design and fabrication and proof testing. Perform an airfoil test at DLR. Finish test stand build-up and checkout including new hub, swashplate, gears, instrumentation and slip ring. Prepare for 40-x80-ft test in late 20 02.

Partners

Army

POC

Mark Fulton Ames Research Center, (650) 604-0102, mfulton@mail.arc.nasa.gov



Goal

The goal of this project is to develop a noise and vibration controller for rotorcraft using enhanced neural network algorithms and adaptive control technologies for noise and vibration minimization. . This supports NASA's goals for Noise, Capacity, Mobility, and Technology Innovation

Accomplishments to Date

The Research Plan was approved May 1, 2001 for 1QFY02 testing in Langley Research Center TDT wind tunnel. FY01 funding received and part time contract staff hired to support code development. Dedicated software licenses purchased to support software development. Control system development and NNET software modifications currently underway to re-host Neural Generalized Predictive Control.

Future Plans / Opportunities

Develop notch filtering on cost function, examine both frequency and/or time domain NGPC implementations using simplified system models. Testing slipped to late 02

POC

Donald Solowaty Ames Research Center, (650) 604-6558, dsoloway@mail.arc.nasa.gov

AT

RAPID Status Summary

Rotorcraft Program

Tasks	Funding Source	Status	Continuation actions
Advanced Configuration			
1. Advance Runway Independent Aircraft Concepts	NASA	Near Complete/future work in doubt	
2. Parametric cost models	NASA	On-going/future work in doubt	
3. Variable Diameter Tilt Rotor (VDTR) Demonstrator	REVCON	Phase I complete/future work in doubt	
4. Swashplateless Flight Demonstrator	REVCON	Phase I complete/future work in doubt	
5. Ducted Fan Investigation	NASA/DARPA	Complete	
Computational Code Development			
1. Computation Modeling of Rotorcraft Aerodynamics	ARMY/NASA	On-going/Army should continue	
2. Computation Modeling and Validation of Hovering Rotor Aerodynamics	Army/NASA	On-going	
3. Real Time Rotorcraft Free Wake Modeling	SBIR	Complete	
4. UH-60 Airloads	NASA/ARMY	Phase I & II compete/future work in doubt	
6. Unsteady Aero	DOE/ NASA	Complete	
5. Applied Particle Image Velocimetry	NASA/Army	Complete	
Tilt Rotor Aerodynamic/Acoustic			
1. Full-Span Tilt Rotor Aeroacoustic Model	SHCT/Base/Army	Phase I & II complete/future work in doubt	
2. V-22 adaptive flow control	DARPA/Boeing	Future work in doubt	
3. Tilt Rotor Descent Aerodynamic 80x120	NASA	Phase I complete	
4. Tilt Rotor Descent Aerodynamic 7x10	NASA/Navy	Phase I complete/Navy funding in FY02	
5. Tilt Rotor Aerodynamic Assessment Committee	NASA/Navy	Complete	
Noise & Vibration control			
1. Active Noise controller XV-15	SHCT/BASE	Complete	
2. UH-60 IBC	NASA/Sikorsky/ZFL	On-going/future work in doubt	
3. Smart	NRTC/DRAPA/Boeing	On-going/future work in doubt	
4. Active Elevon Rotor	Army/NASA	On going/future work in doubt	
5. Intelligent Noise and Vibration Reduction /Neural Generalized Predictive Contro	NASA	Near Complete	